Performance of the CMS RPC upgrade using 2D fast timing readout system

K.Shchablo* on behalf of the CMS Muon Group

*Institute of Nuclear physics of Lyon

Bâtiment Paul Dirac 4, Rue Enrico Fermi 69622 Villeurbanne Cedex, France

Introduction

During Phase II of the LHC program (HL-LHC) the instantaneous luminosity in the CMS experiment is expected to increase by a factor 5-7 [1].

In this case, a new generation of RPC capabilities to sustain high particle fluxes and instrumented with a precise timing readout electronics is proposed to equip the high η muon stations:

$$1.8 < |\eta| < 2.4$$

Improved RPC (iRPC) detectors should be able to withstand particle rates as high as:

$$better\ 2\ kHz \cdot cm^{-2}$$

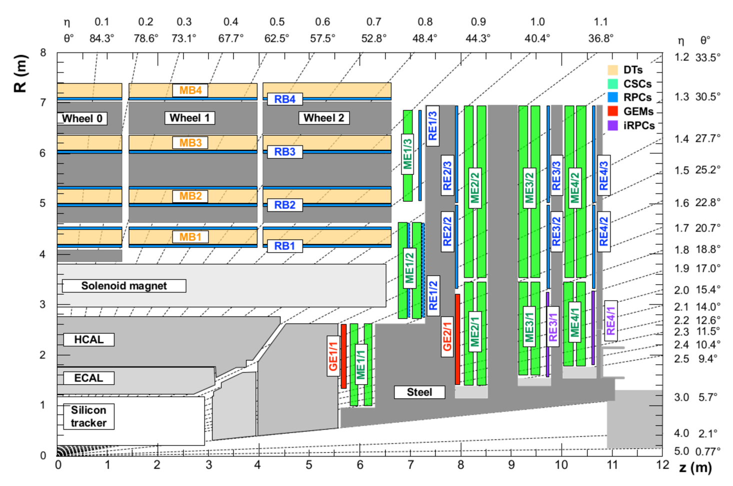


Figure 1: *Layout of one quadrant of CMS. The slots RE3/1 and RE4/1 are to be instrumented by RPC chambers for HL-LHC upgrade.*

Prototype Design

Thinner gap ($2\ mm \rightarrow 1.4\ mm$) in the double gap RPC detector [2] reduces the amount of avalanche charge.

This improves rate capability by reducing the needed time to absorb this charge. To keep the iRPC efficiency high a sensitive, low-noise and high time resolution electronics readout is needed (Fig. 2).

lower charge → less aging → **needs more sensitive electronics.**

higher rate → more combinatory → **needs better space resolution.**

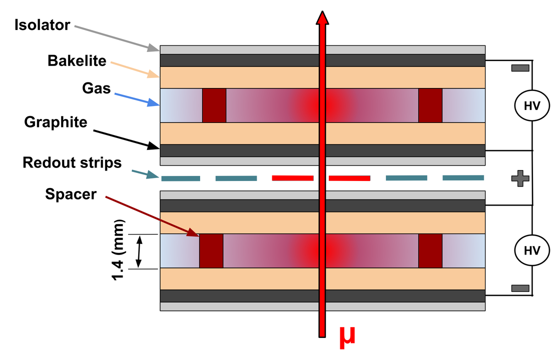


Figure 2: *Double gas gap.*

A strip signal is read out from both strip's ends. PETIROC2A chip [3] with a low-jitters preamplifier is used for the readout (Fig. 3,4).

Thin ($0.6\ mm$) Printed Circuit Board (PCB), $165\ cm$ long, equipped with impedance-matched pickup strips of $0.75\ cm$ pitch, is inserted between the two RPC gaps (Fig. 4).

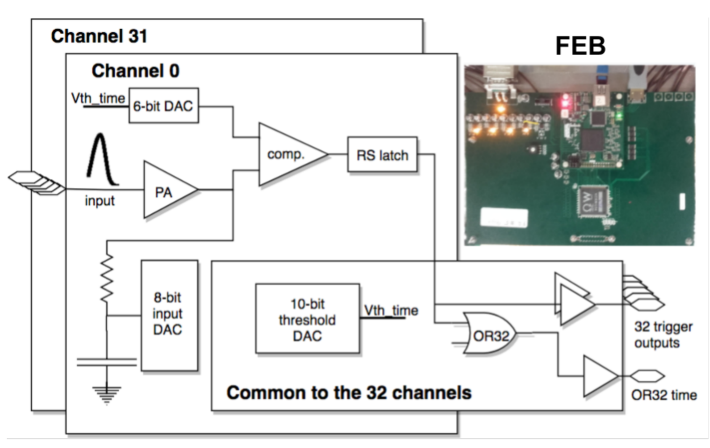


Figure 3: *Front-end electronic.*

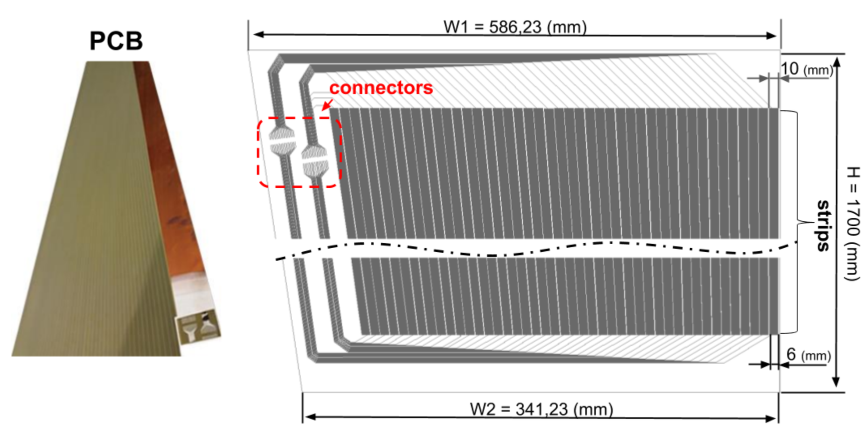


Figure 4: *PCB Layout.*

Performance

To emulate HL-LHC conditions in GIF++ [4]: Muon beam from SPS (Fig. 5) and Source ($14\ TBq\ ^{137}Cesium$) with different Attenuation factors (ATT) allow reaching a rate of gamma cluster seen by the RPC chamber $up\ to\ 3\ kHz \cdot cm^{-2}$ (Fig. 6).

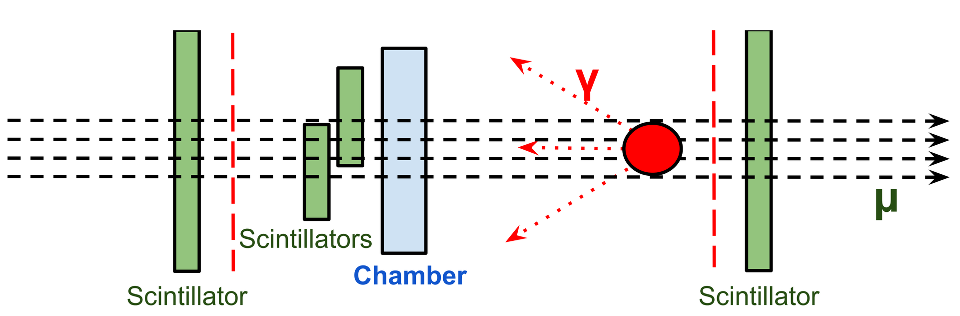


Figure 5: *Setup in Gamma irradiation facility (GIF++).*

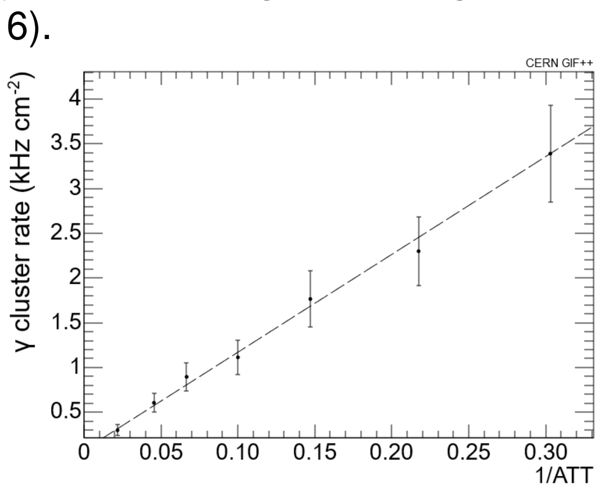
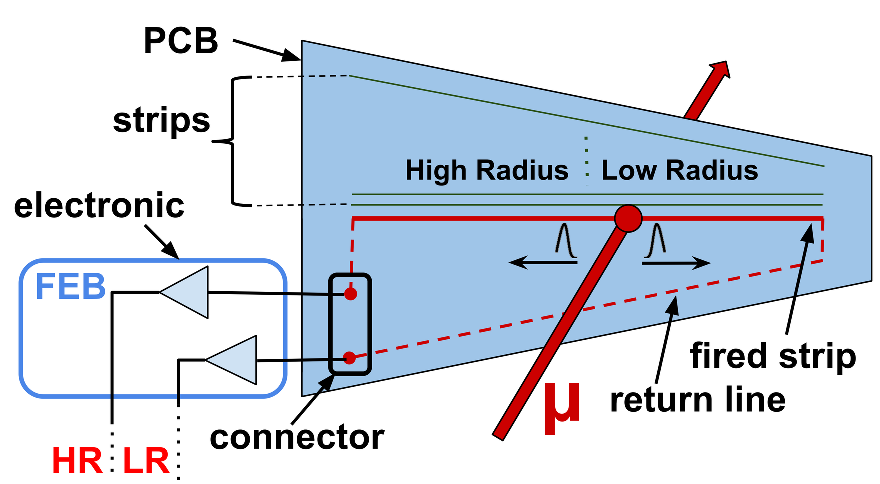


Figure 6: *Background rate.*

Using reference signals from a scintillators-based coincidence unit (Fig. 5) allows calculating efficiency (Fig. 8) as follows:

$$\varepsilon = \frac{\frac{N}{N_{trig}} - \frac{N_{bkg}}{N_{trig}}}{1 - \frac{N_{bkg}}{N_{trig}}} \qquad (1)$$

ε: Muon Efficiency;
N_{trig}: Number of triggers;
N: Number of events for which at least a strip is fired (both ends);
N_{bkg}: Estimated by counting events for which at least a strip is fired (both ends) in a time interval outside that associated to the signal.



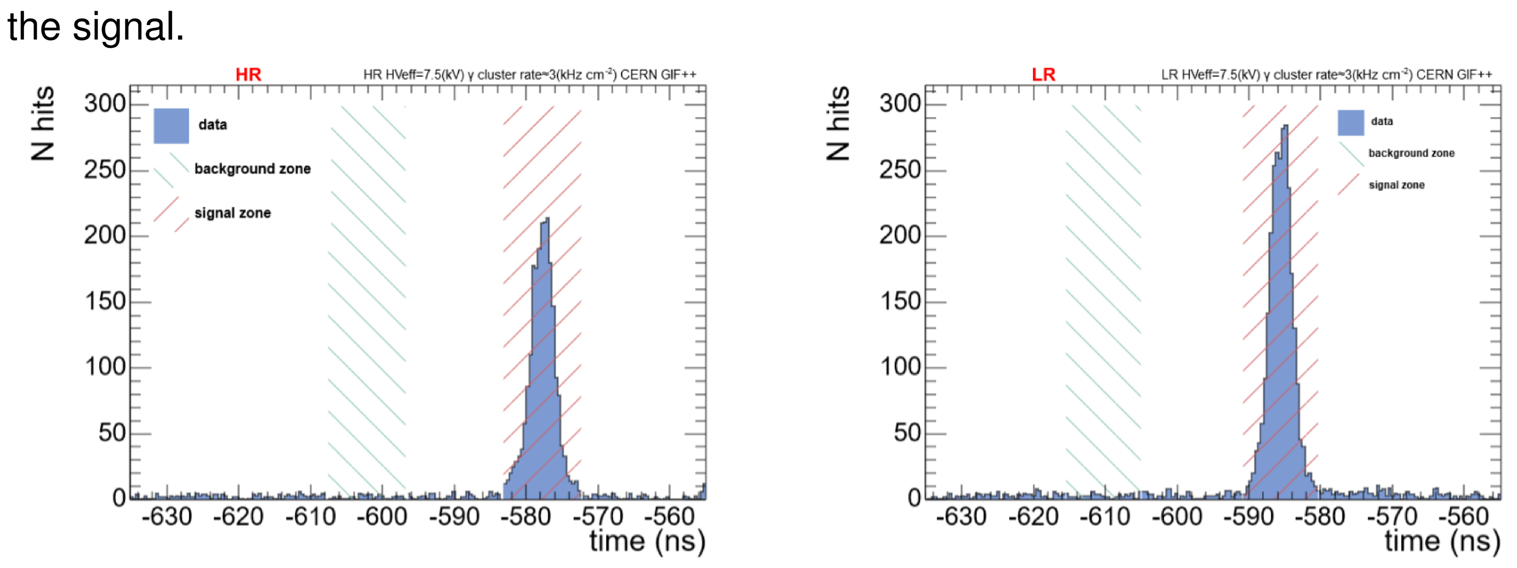


Figure 7: *HR and LR time profiles of strips signals associated to the beam.*

Windows size for events counting are determined by the mean ± 3 sigmas of a Gaussian fit for the signal zone and 6 sigmas in the zone outside the signal region for background zone.

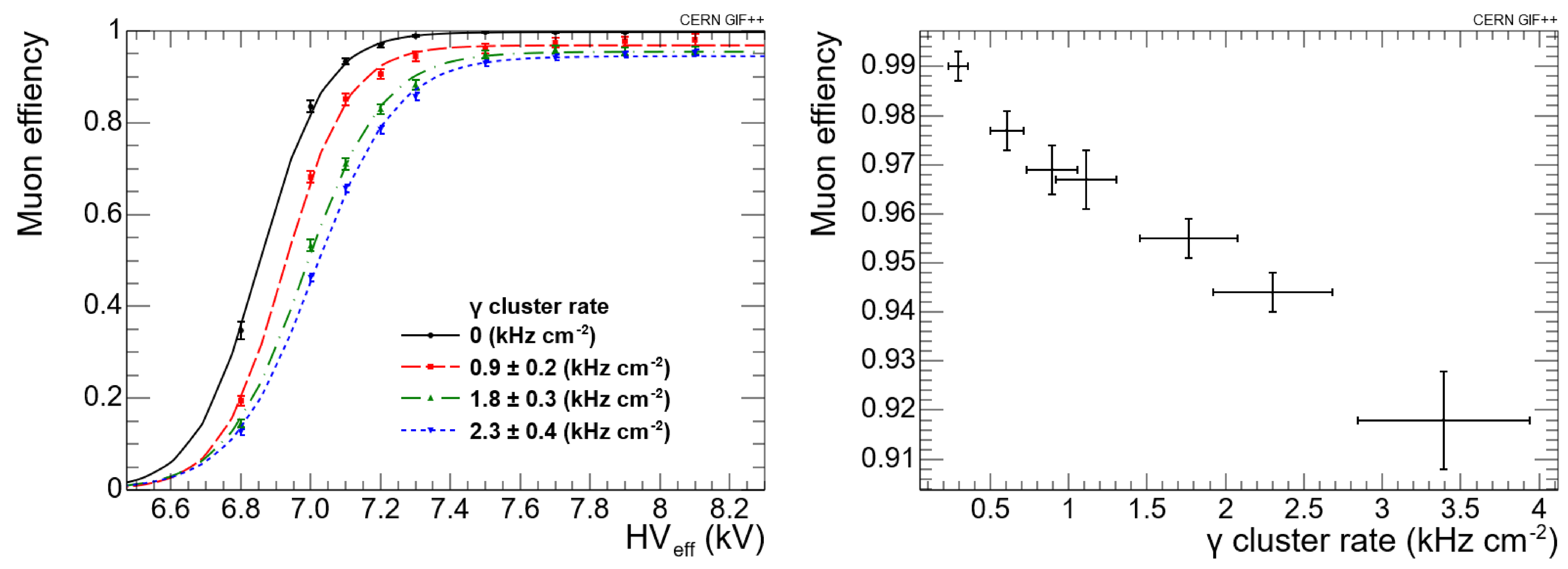


Figure 8: *Efficiency of the chamber with various background levels.*

Note: Effective HV takes into account the change in pressure and temperature with respect to an HV reference value V_0 at given pressure P_0 and temperature T_0.

Linearity and Along-Strip Resolution

A position scan of the chamber was performed in SPS H2 beamline using a muon beam.

The chamber was mounted on $0.1\ mm$ precision movable table (Fig. 9). For each position of the table the time difference is estimated:

$$T = T_{HR} - T_{LR}$$

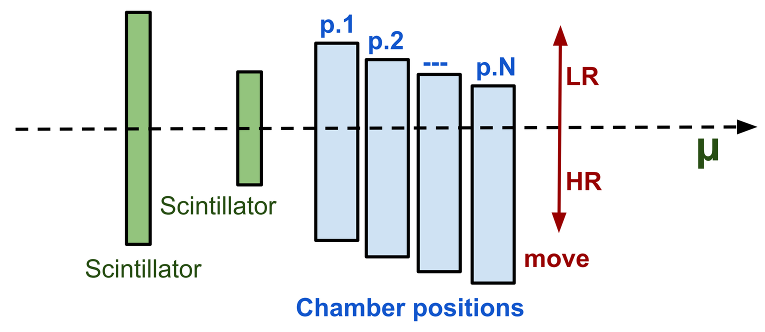


Figure 9: *Setup with the movable table.*

Very good linearity is observed. Maximum deviation is less than $2\ cm$ with respect to the exact value.

With a time resolution of $177\ ps$ and a signal propagation speed in a strip of approximately $5.25\ ns$, the along-strip position resolution is $\approx 1.7\ cm$ (Fig. 10).

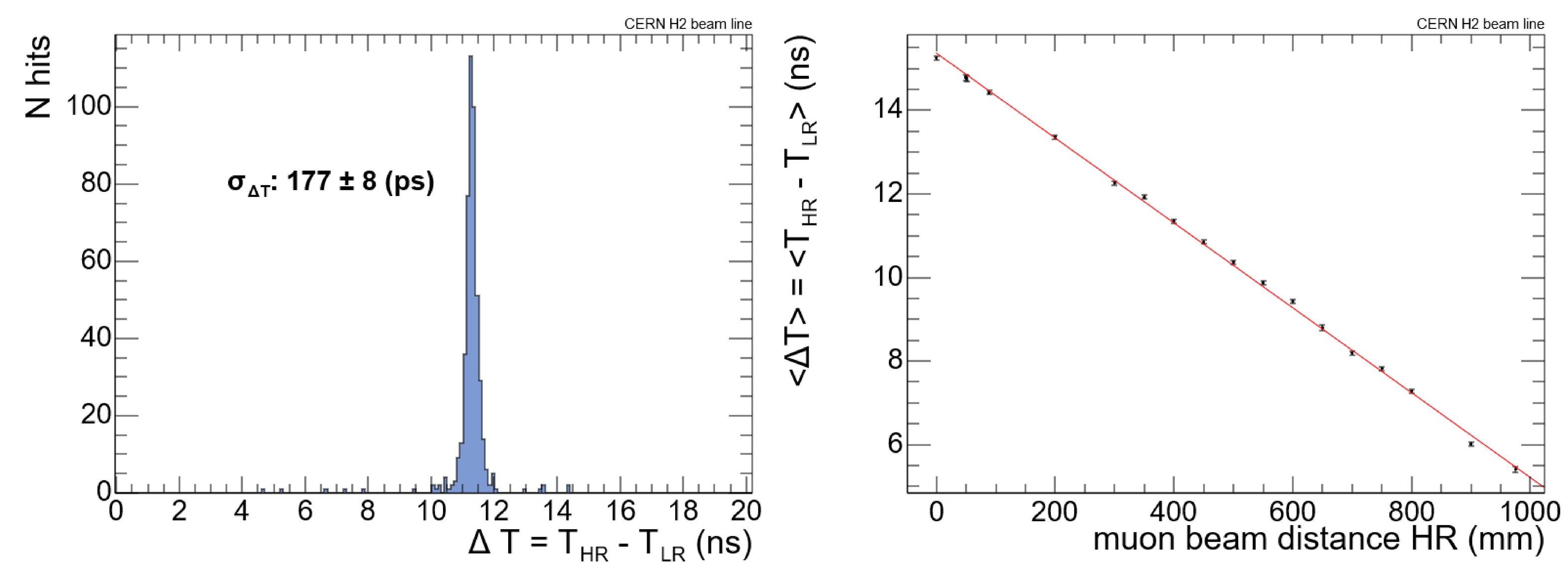


Figure 10: *Strip time resolution and time measurement linearity.*

Absolute Time Resolution

Measured as the resolution of arrival time difference of the signals of two chambers crossed by the same particle divided by $\sqrt{2}$. The assumption is that both electronics are identical and uncorrelated (Fig. 11).

$$\Delta t = ((T^{HR}_{prot.1} - T^{HR}_{prot.2}) + (T^{LR}_{prot.1} - T^{LR}_{prot.2}))/2$$

$$\Delta t = t_1 - t_2 \rightarrow \sigma_{\Delta t} = \sigma^2_{t_1} + \sigma^2_{t_2} - 2 * \sigma_{t_1} * \sigma_{t_2}$$

$$<\sigma^2_{\Delta t}> = <\sigma^2_t> + <\sigma^2_t> \quad if\ detect.\ are\ independ.$$

$$<\sigma_t> = \frac{<\sigma_{\Delta t}>}{\sqrt{2}}$$

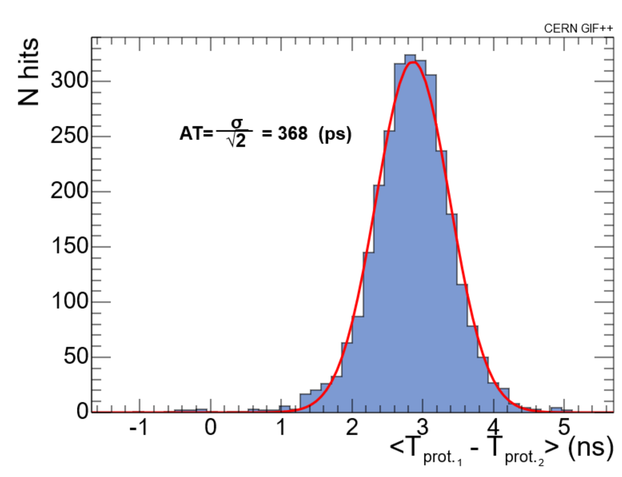


Figure 11: *Absolute time resolution.*

Conclusion

A new RPC technology to equip two stations of the high η region of the CMS muon spectrometer is proposed and validated on real size prototypes. The resulting detector fulfills all the requirements: space resolution better than $1.7\ cm$, absolute time resolution of $\approx 370\ ps$ and an efficiency of 95% for the maximum expected background rate of $2\ kHz \cdot cm^{-2}$ [1]. The detector is found to be uniform over $1\ m$ length.

References

[1] CMS Collaboration, The Phase-2 Upgrade of the CMS Muon Detectors, Tech. Rep. CERN-LHCC-2017-012. CMS-TDR-016, CERN, 2017.

[2] K. S. Lee, et al. Study of Thin Double-Gap RPCs for the CMS Muon System. Journal of the Korean Physical Society. 73. 1080-1087. 10.3938/jkps.73.1080. 2018

[3] J. Fleury et al., Petiroc, a new front-end asic for time of flight application, in 2013 IEEE Nuclear Science Symposium and Medical Imaging Conference (2013 NSS/MIC), pp. 1–5, Oct, 2013.

[4] M. R. Jakel et al., CERN-GIF++: a new irradiation facility to test large-area particle detectors for the high-luminosity LHC program, PoS TIPP2014, 2014.